# Supporting peer-learning with Augmented Reality in neuroscience and medical education

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**Abstract.** XR (VR and AR) is being integrated into higher education to facilitate the teaching of complex concepts and presenting learning material difficult to explain using other means. An interesting pedagogical approach is to enable students to help each other in achieving their learning goals. Collaborative- and peer learning are among the pedagogies that can enable students to work together towards their learning outcomes. Such pedagogies can also be valuable for hybrid learning. VR is commonly preferred for multiuser collaboration. Nonetheless the role of AR for collaboration is increasing. In this paper we discuss our approach and on-going work towards developing a framework for supporting collaborative and peer learning through AR and how an AR-based neuroanatomy app can be used for peer-learning.

**Keywords:** Augmented Reality, Peer Learning, HoloLens2.

## 1 Introduction

Applications of XR (Virtual Reality, Augmented Reality) in education use visualization, simulation, interaction and manipulation as techniques that support experiences to help educators achieve a learning goal.

Our research and development work focuses on using XR for education and training. This includes creating a set of virtual reality (VR) applications for training young job seekers [5]. We also have previous experience in developing AR for education and medical training guides [1], including the research on and development of AR-based applications for teaching neuroanatomy in higher education.

For several years, we have performed research on VR/AR supporting collaborative and remote learning, both prior and during the COVID-19 pandemic [10]. The experience in developing such applications led to develop a methodology to guide, inform and facilitate development of VR applications for training.

Our research is carried out around a dedicated XR lab where we promote immersive technologies and offer educators opportunities to familiarise themselves with XR [4]. An important part of our research is to explore new ways to integrate and increase adoption of immersive technologies in higher education. Additionally, we are part of consortia investigating use of augmented reality (AR) in education. In particular, this study is a part of the i-PEAR project: Inclusive Peer Learning with Augmented Reality. This is a three-year Erasmus+ project KA203 - Strategic Partnerships for higher education- with a mission to explore pedagogies and technologies that have the potential to enhance students' motivation, engagement, and autonomy.

The goal of this project is to investigate how to better integrate pedagogies with AR in higher education, test and develop methodologies to use AR in teaching. The goal of this project is being pursued through a two-part strategy. One part consists of interviewing lecturers and explore with them the possibilities of using peer learning. The second part is exploring peer learning as a pedagogy for technology enhanced or supported learning.

## 2 Pedagogies for use of AR in education

Social Learning is an ancient pedagogy; Plato and Aristoteles used to teach through dialogue with their students. In the contemporary history of learning theory, the father of social Learning, Albert Bandura [2], claimed that learning is not an isolated act, but we can learn by observing others.

Peer learning frames the new capital of the infosphere. Students and educators find 'learning friends' as co-travelers to help them acquire new skills or digest information as creative work with others that provide micro-scaffolding in class and online. The Peer-to-Peer instruction model, originated by Eric Mazur in 1997 [9], offers significant evidence that it makes learning more efficient, collaborative, and empowering for students. Peer instruction involves students actively in class requiring previous preparation before coming to class and using lecture time to explain concepts to their fellow students [3] [13]. AR applications are being used for learning in technical and non-technical subjects [12] and it is required to look beyond the technology and investigate what pedagogies and methodologies achieve better learning results. This need has been a subject of research for long and as the technology offers new affordances it is also necessary to continue investigating how are we using the latest AR applications in education.

Literature reviews often associate the use of AR in education with approaches such as situated and collaborative learning, including of course other approaches derived from constructivism [6]. Garzon's work singles out collaborative learning as the only approach to have a large effect in learning outcomes. It is worth therefore to further explore the benefits from similar pedagogical approaches.

Theoretical frameworks, as listed by McNeal et al. [8], can inform an investigation of AR in education, considering different pedagogical objectives ( Table 1).

**Table 1.** Frameworks for studying AR as presented by Mcneal et AL.

| Framework | Description |
|---|---|
| Mental-models framework | Representations of external thinking phenomenon |

| | |
|---|---|
| Spatial-cognition framework | Knowledges and beliefs about spatial properties |
| Situated-cognition framework | Learning connected to authenticity, context and culture |
| Social-constructivist-learning | Social and collaborative aspect of learning |

For our current work it is important to consider collaborative and social aspects of learning as explained in the following section. As mentioned previously, research in VR in our group has an increased focus in multi-user and collaborative solutions [10]. We are extending that focus to AR as well. In previous AR development work with HoloLens1, we evaluated implementing multiuser collaboration for training in a novel medical procedure, but it proved cumbersome at the time. Later work using Magic Leap [1] offered better chances for implementing collaboration than we experienced earlier with development for HoloLens1. HoloLens2 offers an improved platform to explore collaboration in education, in comparison with other see-through AR headsets in the market.

In our work we have identified a potential for AR to support peer instruction in education. Peer instruction and peer learning relations remain under-researched. We believe that AR-based instruction can contribute to give insights into the mentor-mentee relations in peer learning. We contribute with this work to gain more insight into the possibilities of AR for peer learning. We use a case for teaching brain anatomy using a custom AR application developed for HoloLens2 as a way to investigate peer-learning. This research is also framed in the context of an Erasmus+ project i-Pear as member of a consortium using AR for peer learning. The goal of the project is supporting and empowering European educators with digital and pedagogical competences. The focus is on AR tools and collaborative learning approaches such as peer learning.

## 3 An educational tool for neuroscience and medical education

Medical education used physical samples such as human tissue or cadavers intensively several years ago to educate and train students. That practice is in recent years in decline in some medical faculties and lecturers consider other tools and approaches to educate and train students [7].

Teaching in neuroscience, particularly neuroanatomy, focuses on the structural organization of the nervous system, the brain and its structures. The difficulty with some educational approaches is that they use flat images in teaching the brain structures. The students do not see the whole volume of the structure often enough and makes it difficult to gain understanding of the spatial relations between the different structures in the brain.

A master project carried out in our lab [11] investigated the feasibility of AR as an educational tool for neuroanatomy teaching and for independent exploration at the Nobel-prize winning Kavli Institute for Systems Neuroscience. An important research objective in that project was to investigate a collaborative experience using different AR displays (HMD and smartphone).

In this project holographical visualizations of macroscopical rodent brain dissections (as rodents are extensively used in research activities at Kavli Institute) are used for teaching the organization of the structures in the brain [11]. This reduces the need for physical brain material. In addition, the COVID-19 pandemic imposed additional constraints on educational process, limiting students' access to the labs. The result of the project was the development of the Nevrolens application [11], addressing these challenges.

The Nevrolens app is a Unity-based app developed for HoloLens2 see-through HMD and android. The app presents the user with a brain visualization (see Figure 1). Floating text boxes were implemented in AR to label and provide information on the brain structures.

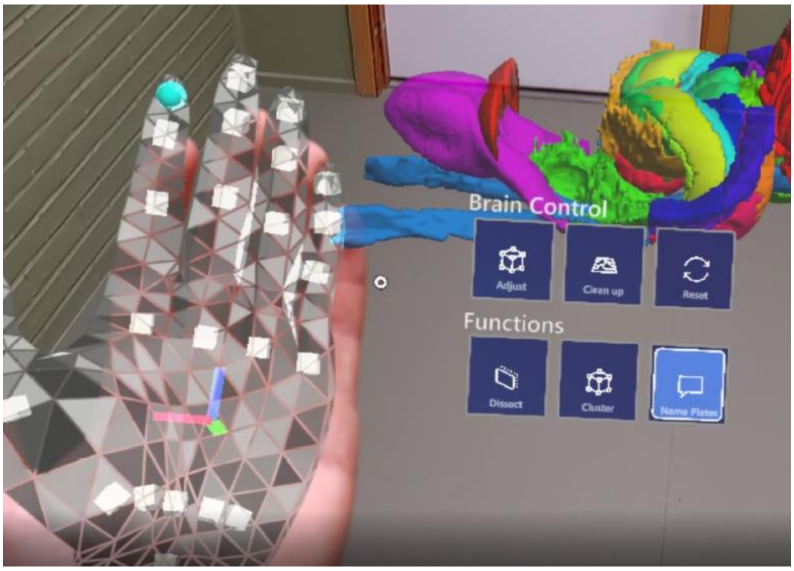


*Figure 1 A screenshot of the neuroanatomy application user interface.*

At start the user is presented with a rat brain structure. The structures of the brain are presented in different colours (see Figure 2). Functionality was implemented to support pointing to a brain structure, selecting and manipulating it, with corresponding tools. Additionally, the user can use a cutting plane to perform a virtual dissection and look inside selected structures. Text boxes will inform the user with the name of the structure as well as a short description.

Most of the coloured structures can be seen individually or collaboratively. It can be difficult for students to gain an understanding of the spatial relations of the brain structures. The AR visualization allow the students to visualize the brain structures from different points of view, but also see the volumetric relations between the structures. The functionality is, therefore, important so students can access brains structures that are occluded by others. If this is done with flat (2D) images, it probably is higher cognitive load to comprehend the spatial relations.

Textures and shapes also play an important role and the students can potentially be better at recognizing the shape characteristics of important structures as well as recognizing features in the surface of each of them.

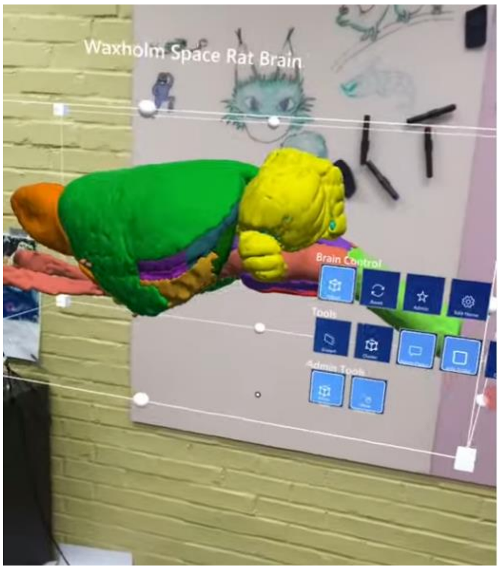


*Figure 2 Screenshot of brain structures in AR app*

Of course, the colours are an abstraction which is necessary to supplement the student's digital skills. Even if the student is not experienced in digital tools, the different colours provide a visual feedback and contrast than helps in identifying different parts.

## 4 AR-based peer-learning with HoloLens2 and Android devices

Teaching of neuroanatomy physiology requires a detailed understanding of the anatomical structure of the brain. A lecturer in our university had been involved in creating a tool for teaching anatomy in VR and approached our group to explore potential improvements to the application.

Discussion of their needs showed a possibility to use AR. There were several motivating factors to explore a new application. A major factor is that teaching of neuroanatomy is still highly dependent on well-trained lecturers. There is an interest by the collaborating lecturer in training others into teaching neuroanatomy.

The hybrid learning adopted at our institution as a consequence of pandemic regulations also encouraged exploring new ways to deliver learning content but more importantly, to offer possibilities of peer-to-peer socialization among students. Students highlight the lack of social contact as a negative consequence of the use of online teaching due to pandemic regulations in higher education. An additional factor was investigating techniques for manipulating the digital representations of the brain structures, for example different uses of cutting planes.

The AR application is an improvement over a previous application created for single-user VR. The new application was developed as part of a master's project in collaboration with a lecturer in neuroanatomy at our institution. The app developed for HoloLens2 enables visualizing and manipulating a digital rat's brain generated from MRI scans. The brain structure can be separated in relevant physiological units.

From the perspective of peer and hybrid learning it was important to have the possibility of a shared view of what the user (either lecturer or a fellow student) wearing the HoloLens headset could see. It is still common for many AR apps for headset that only the user wearing the headset can see what is happening. This makes it difficult to share their experience with others either in the same physical space or remotely. The AR app addresses these requirements.

Additionally, it was important that one user could interact with the digital brain and manipulate it whilst the other user could be able to see the consequences of that manipulation (see Fig. 3).

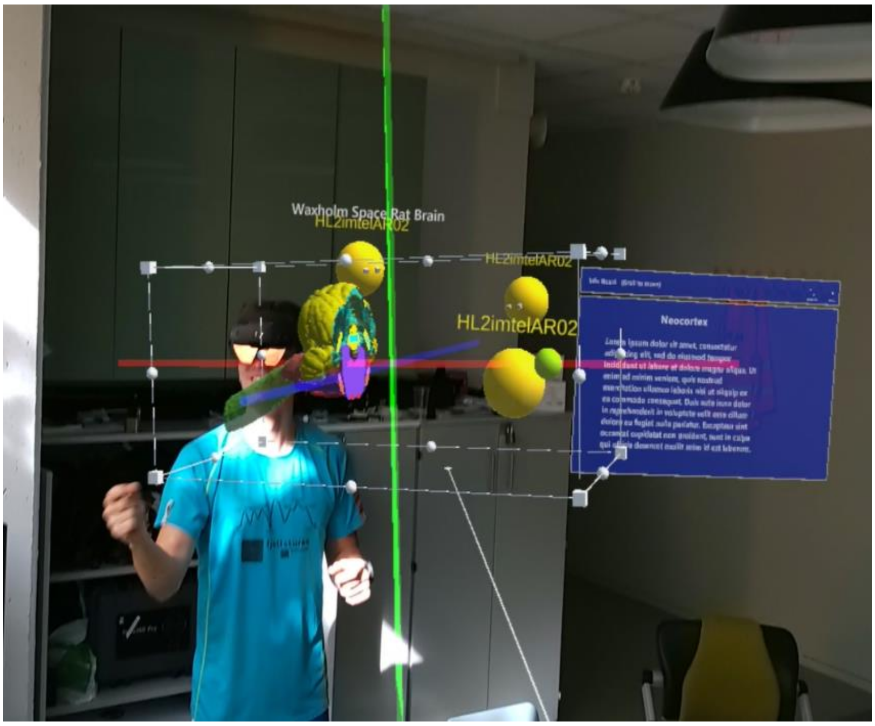


**Fig. 3.** A screenshot of a tester interacting with a colleague using the neuroanatomy application.

The content can be seen simultaneously by a user with the HMD and another on an Android smartphone. Both Hololens2 and Android users could manipulate the holographic brain. In addition, Microsoft/HoloLens 2 introduced the Windows device portal, which is a useful feature to stream the app to a monitor.

This combination of displays enables a group of up to five individuals to take part in a session. One lecturer or student can therefore explain to classmates about the topic at hand. Since they have a shared view of the brain structure, students can explain to each other, point and show. A usability study was carried out with a small number of participants to evaluate the AR app.

# 5 Evaluation of the Nevrolens app

The evaluation of the application was severely hindered by pandemic restrictions. It made difficult to recruit significant number of participants for testing at the time. This is a characteristic noticed in many papers with research carried out in 2020 and early 2021. The nature of the discipline added to the difficulty since there are not that many students on the neuroanatomy subjects available for testing. Nonetheless, a simple evaluation was carried out to evaluate the test and the peer-learning experience.

## 5.1 User evaluation

Students and teacher have been consulted through the whole process of app development. A final user evaluation was carried out with five first-year medical students [11]. The students filled a consent form and a knowledge questionnaire. The students also answered a system usability Scale (SUS) questionnaire at the end.

The teacher was present leading the session. Two students wore the HoloLens 2 and another two used android smartphones. The teacher followed the session watching in a computer monitor.

The knowledge questionnaire was carried out to see if there were any learning gains from using the app. Two knowledge questionnaires were carried out. One questionnaire was carried out before using the app. Another knowledge questionnaire was filled after the test. The questions related to neuroanatomical knowledge [11].

The neuroanatomical knowledge test showed a slight better performance in the after test (see Table 2). There was a maximum of 26 points possible. The sample is too small to make any assumptions, but the outcome is interesting and encourage us to carry out further tests in the future to validate learning gains.

*Table 2 Results from knowledge tests*

| | Before | After |
|---|---|---|
| Subject 1 | 13 | 14 |
| Subject 2 | 10 | 17 |
| Subject 3 | 12 | 13 |
| Subject 4 | 10 | 13 |
| Subject 5 | 6 | 13 |

The SUS was answered by six participants. One participant did not answer the questionnaire. The questionnaire was based mostly on use of the HoloLens. The mean score was 79. Only one sample was collected for android with a value of 75.

Unfortunately, the results are very limited by the strong reliance on data collected for the HoloLens. Future work will include a more balanced study with both interfaces.

Qualitative data suggests a positive experience by the participants, which is encouraging for further work. Some remarks, collected by the master student in his work [11] from the participants in the session include the following:

"I learned about the three-dimensional placement of structures in the brain and how the structures are placed relatively to each other"

"I feel I learned more about the anatomy of the rodent brain while picking it apart and puzzling it back together. However I wish I had more time to read the description of the different brain parts as well."

In the preliminary evaluation of the app, the educator interviewed maintained the importance of collaboration for learning and engagement via the app. At the same time, he is committed to experimenting more on it in the future. On the other side, the six students replied on an online survey claiming that all fell more responsible for their learning and enjoyed working with their classmates.

Four questions were asked to the participants regarding their experience with peer learning. Six participants answered. The first question was: "Did you like the approach of peer learning (working with and teaching your classmates? "The answers were 3 neutral, and 3 strongly agree. The comments on the answers were: "You can share knowledge and discuss facts to further solidify the theory", "Learning alongside others is very fun, especially after having had remote electronic learning", "Because it is interactive and communicative ".

The second question was, "Were you more interested in teaching each other and sharing content with your peers and AR tools? 1 participant disagreed, 1 participant was neutral, and 3 agreed. The comments on the answers were:" It was exciting to try the technology with a classmate, and it gave a new dimension to the cooperation ", "Didnt feel it", "Because this is a great new way of teaching and learning".
The third question was, "Did this learning approach make you feel more responsible for your learning?" One participant disagreed, three were neutral, one agreed, and another strongly agreed. The last question was, "Do you think it would be useful in other courses/fields of study as well?" Two participants agreed, and four participants strongly agreed.

Although the research sample is small for firm conclusions, the pilot study indicated that further experimentation is worthwhile because most respondents described it as a positive experience while taking responsibility for learning and sharing activities with others. The individual difference shows that we can’t have a one-fits-all approach, but we ought to allow more choices for the students. It is important to note that the instructional design of the task and the pairing of students in small groups may have also affected the learner's understanding of the P2P pedagogy and its use. Therefore, more research is needed to fully understand the potential of the P2P methods and the app.

## 6 Discussion and future work

The ongoing COVID-19 pandemic imposed new requirements on the educational process, with the increased need for digital solutions and support for remote collaboration between lecturers and students. This was the primary motivation for developing Nevrolens app to facilitate remote teaching and dissection of rat brain anatomy for neuroscience students. In addition, we wanted to explore the affordances of high-end AR (HoloLens 2) for peer-learning. The Nevrolens application was tested in a number of small-scale trials with neuroscience students and teachers during 2021. Sone of the evaluation results are presented in this paper. A mixed-methods evaluation has been carried out and the results are being analysed. While the results from these trials are limited, they indicate the application to be of value in educating and enabling peer learning among medical and neuroscience students. The application is currently being developed further in collaboration with stakeholders in Norway, Europe and Canada to support a wider range of anatomical models (such as human pelvis) and to improve user interface, supporting several learning tasks, e.g. students posing questions to each other about different anatomical parts and sharing their dissection progress with peers and teachers.

We have benefited from communications functionality supported by the HoloLens 2 that enabled developing a collaborative app. However, the current version does not support voice chat, making it problematic to evaluate peer learning in fully remote settings. We are currently working on the voice chat feature to be tested in remote anatomy educational sessions between collaborating European universities, including both HoloLens 2 and Android device users. We are also planning to extend the trials to cross-Atlantic peer learning sessions with our collaborators in Canada, though with the current region-based system in Photon network, this might impose additional challenges.
Future work also includes doing more peer learning evaluations with AR for teaching other topics in anatomy as well as other higher education subjects. For the time being, the research informants' number is very small to conclude, but there is a strong indication that we need to investigate more peer learning with AR in the partners' countries: Norway, Germany, and Greece within the frame of i-PEAR project.

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